



## Responses of carbon and water fluxes following drought events in combinations with warming and elevated CO<sub>2</sub>

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# Responses of carbon and water fluxes following drought events in combinations with warming and elevated CO<sub>2</sub> in a semi-natural temperate heath ecosystem

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climate

An aerial photograph of a field experiment. The landscape is a mix of brown, dry grass and patches of green. A network of white pipes or roads runs across the field, connecting several experimental plots. Each plot is marked with a yellow and red rectangular sign. Some plots also have a green circular marker. In the top left corner, there is a logo and three text boxes. On the right side, there is text describing the soil and plant species.

# clima!te

FACE [CO<sub>2</sub>] = 510 ppm

Temperature [T] : + 2 °C  
(Nighttime IR-reflectance)

Drought [D]: Rain exclusion  
Campaigns

Sandy soil

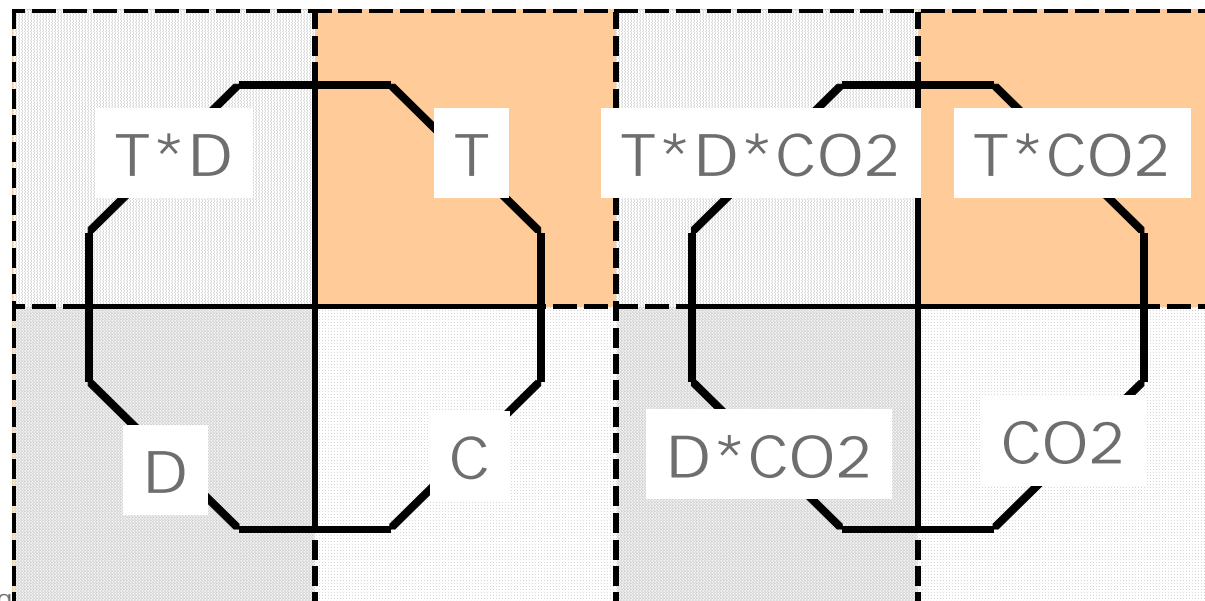
*Calluna vulgaris*

*Deschampsia flexuosa*



Sted og dato (Indsæt --> Diasnummer)  
Dias 4

## Experimental Setup



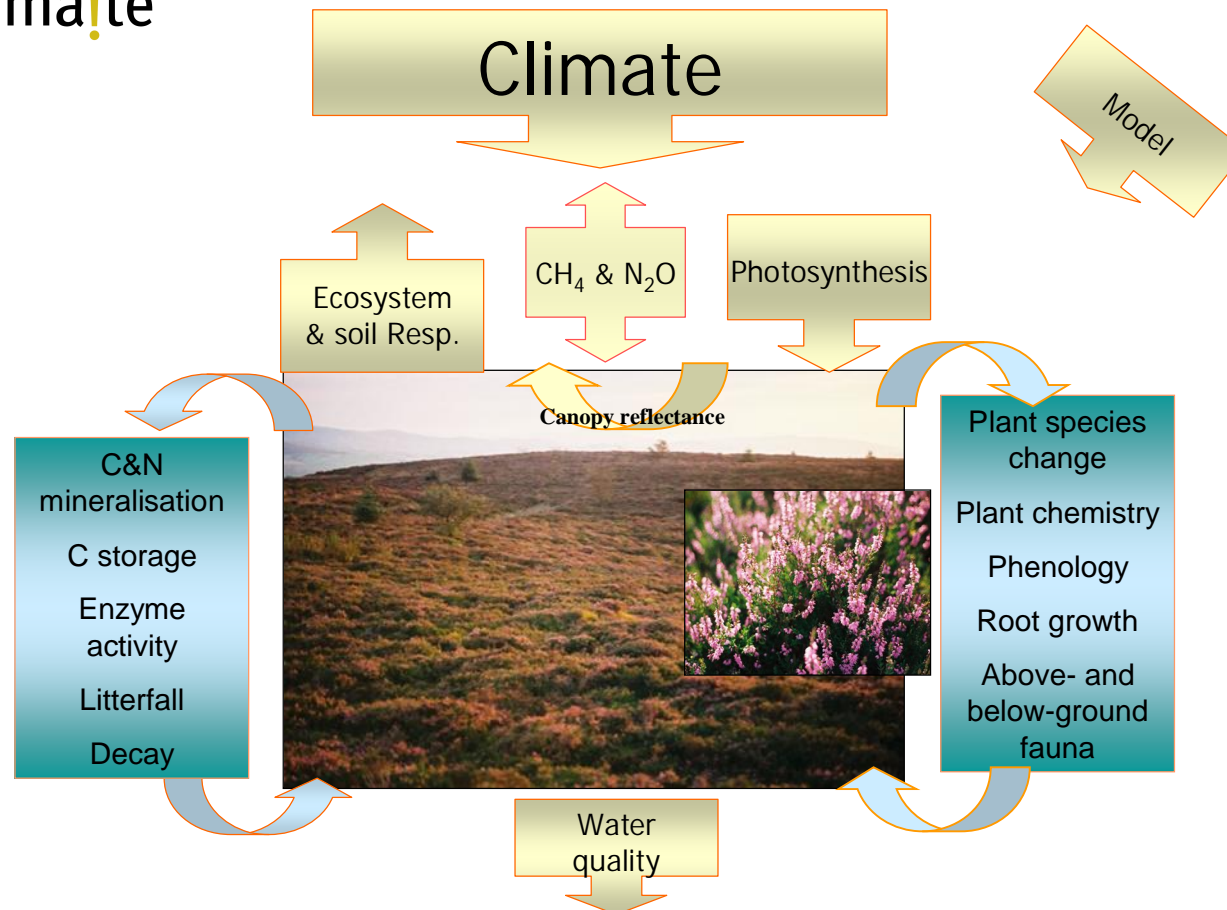
x 6

Sted og  
Dias 5



## Studies of Ecosystem processes and the responses to climatic changes

climaite





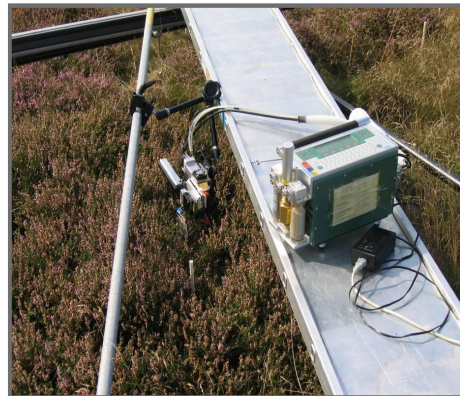
## Plant Ecophysiology:

Photosynthetic Performance of *Calluna vulgaris* and  
*Deschampsia flexuosa*

Responses to treatments (short vs long term)

Seasonal variation

Photosynthesis Model







Sted og dato (Indsæt --> Diasnummer)  
Dias 8

## Measured and *modelled* photosynthetic parameters

Sink Side:

Net Photosynthesis

Respiration

Stomatal conductance

Mesophyll conductance

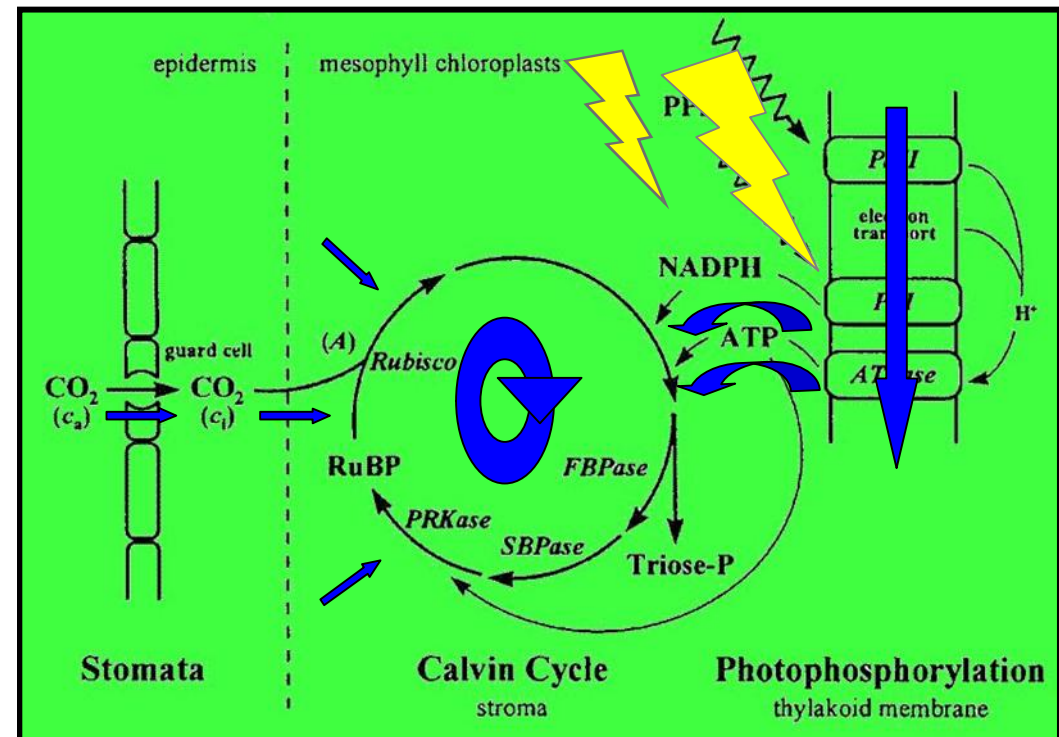
Transpiration

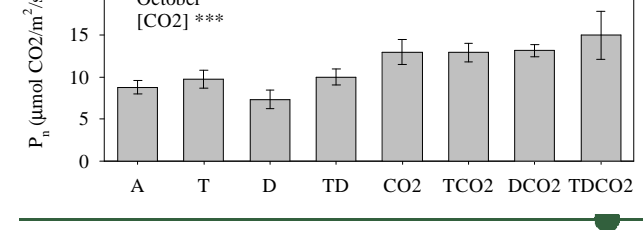
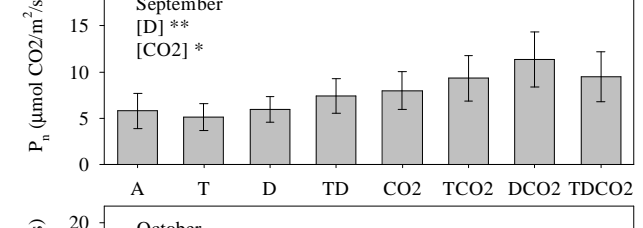
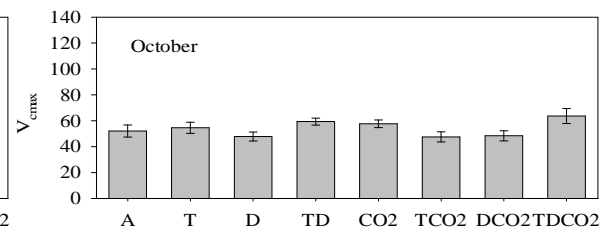
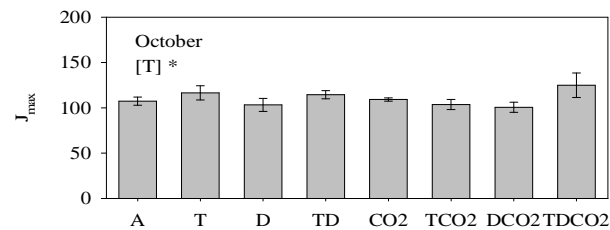
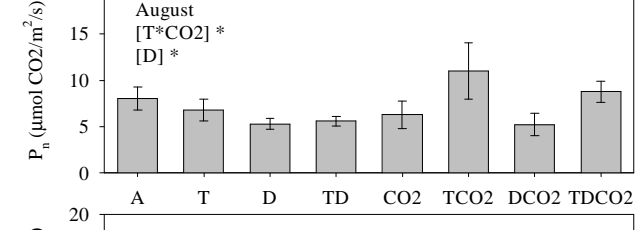
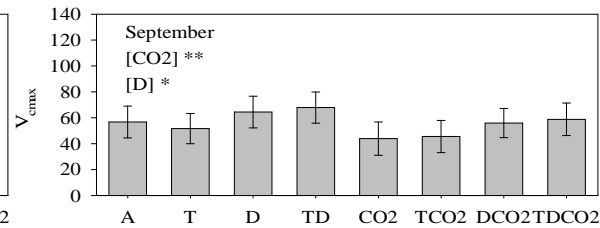
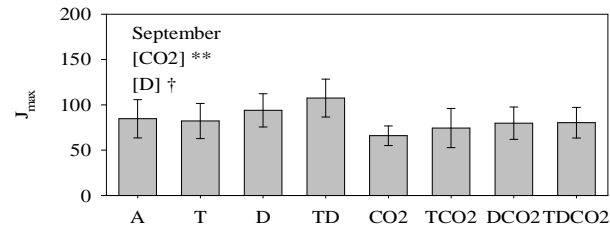
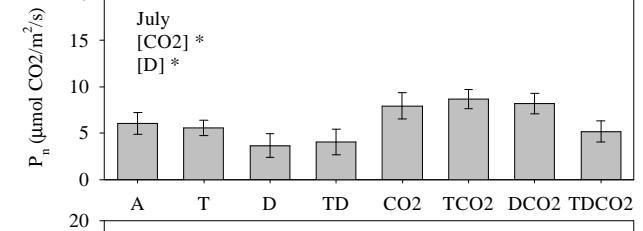
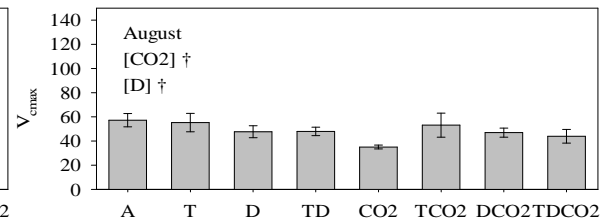
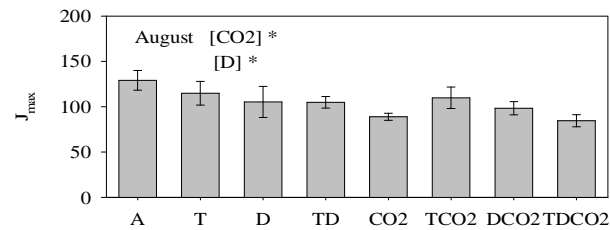
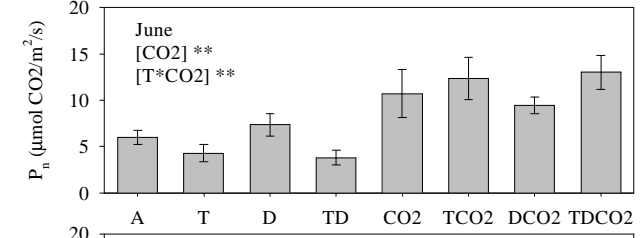
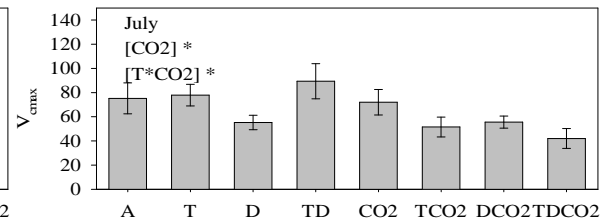
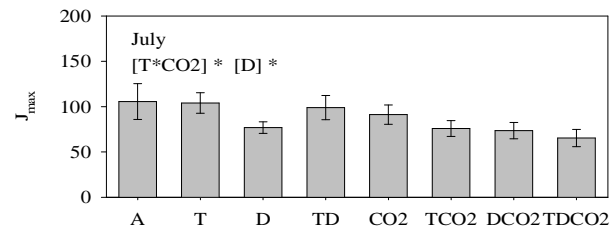
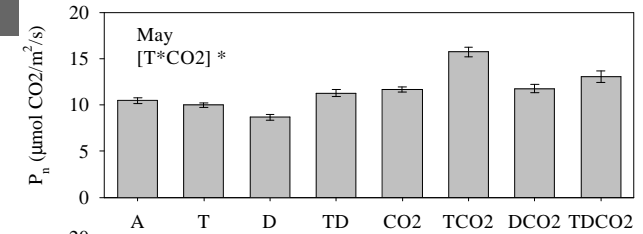
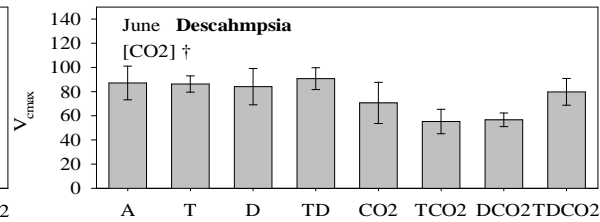
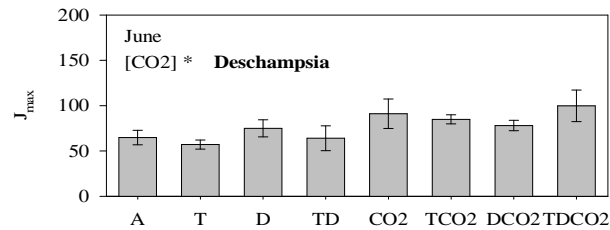
$V_{cmax}$ ,  $J_{max}$  and  $R_d$

Source Side:

PSII performance

Electron transport



***Deschampsia*  $J_{\max}$  and  $V_{\max}$ .**Left panels are Maximal velocity of RuBP regeneration,  $J_{\max}$ . $P_n \rightarrow$ Right panels are Maximal velocity of Rubisco carboxylation,  $V_{\max}$ .

## Working hypotheses

### Passive night warming [T]

- Increased length of the growth season
- Shifts in phenological phases
- No direct impact on daytime plant performance
- Increased sesonal Carbon input and Water consumption

### Summer drought [D]

- Plant water potential
- Stomatal closure
- Reduced photosynthesis

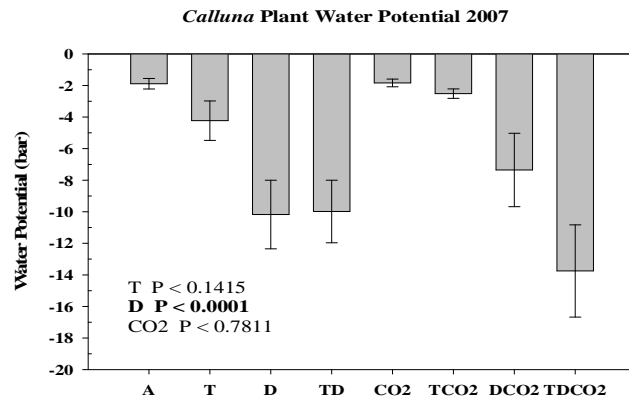
### Elevated CO<sub>2</sub> [CO<sub>2</sub>]

- Increased growth
- Shift C-N ratio
- Photosynthetic down regulation
- Increased Water Use Efficiency

Following slides: Data from summer 2007 late in the drought period



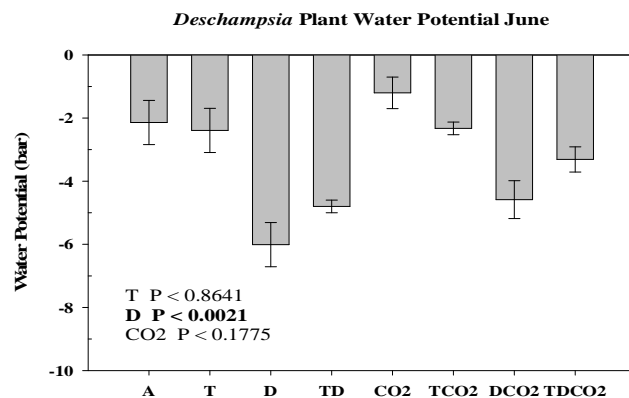
## Plant water potential



- Site heterogeneity and large variation

### *Calluna* (Ericoid dwarf scrub)

- Down to -39 bar (-3.9 MPa)
- Significantly affected by drought
- No effect of elevated CO<sub>2</sub> and T



### *Deschampsia* (grass)

- WP level about half of *Calluna*
- Significantly affected by drought
- No effect of elevated CO<sub>2</sub> and T

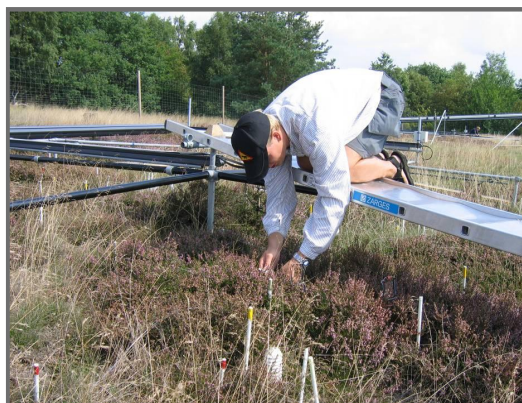
NDVI decreases during drought  
 Pronounced grass wilting  
 Very few Callunas with visual symptoms of drought

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 Dias 12





climaite

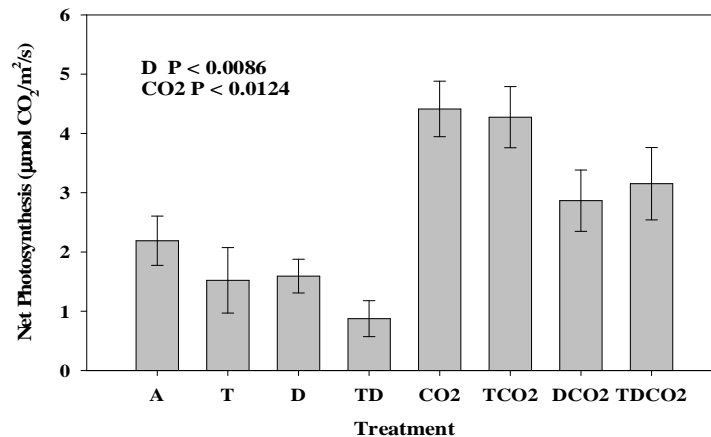


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Dias 13



## Net photosynthesis under field conditions

Net Photosynthesis at field conditions *Calluna vulgaris* august 2007

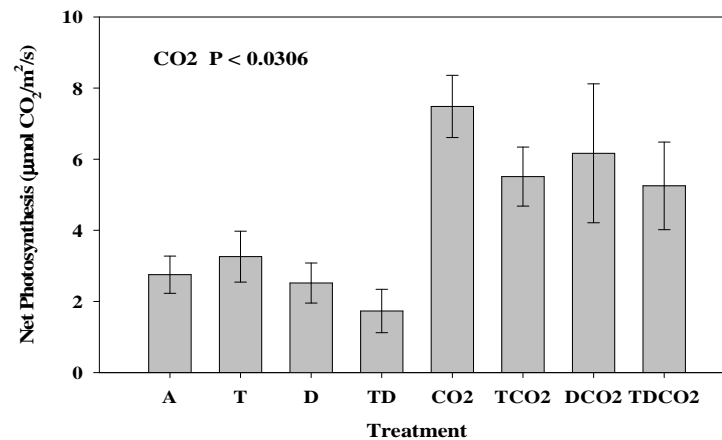


Data extracted from  
A/Ci- curves

### *Calluna*

- CO<sub>2</sub> fertilization
- Negative impact of drought - also in interaction with CO<sub>2</sub>

Net Photosynthesis at field conditions *Deschampsia flexuosa* august 2007



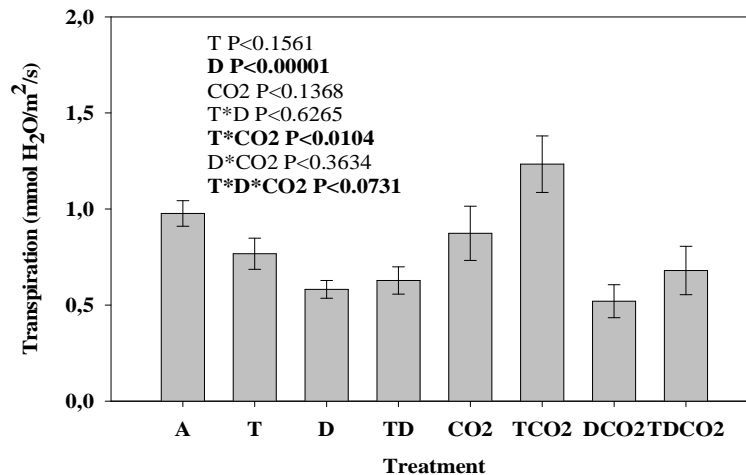
### *Deschampsia*

- Rate of photosynthesis higher than *Calluna*'s
- CO<sub>2</sub> fertilization
- No drought effect ("Filthy Few" ?)



## Transpiration at field conditions (Data extracted from A/Ci curves)

Transpiration at field conditions *Calluna vulgaris* august 2007



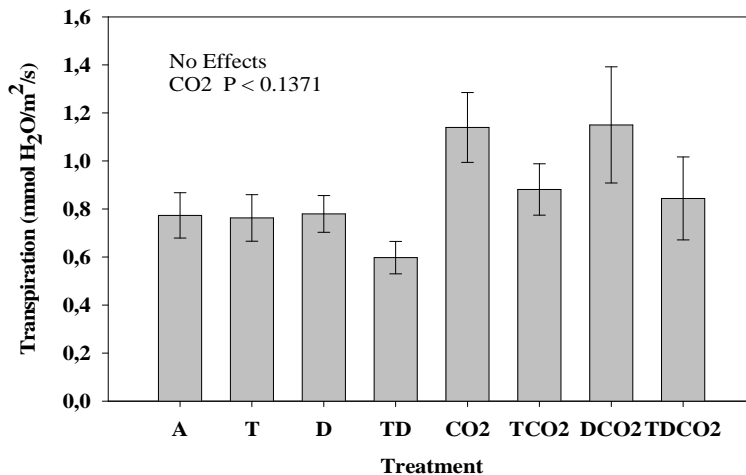
Larger variation in FACE plots compared to non fumigated plots

About same level of water consumption in the two species

### *Calluna*

- Negative impact of D
- Interaction of drivers  
T\*CO<sub>2</sub>, T\*D\*CO<sub>2</sub>

Transpiration at field conditions *Deschampsia flexuosa* august 2007



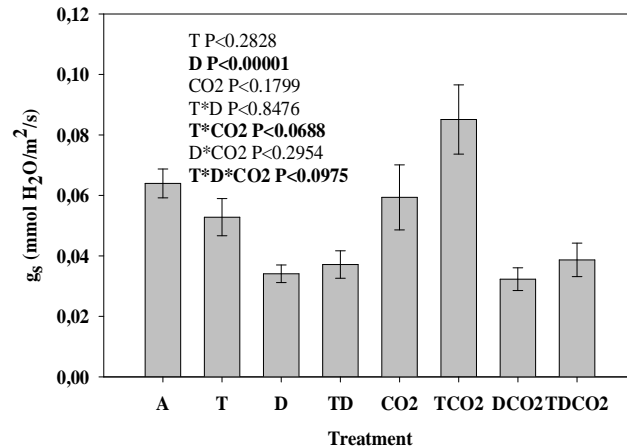
### *Deschampsia*

- Increased water consumption in FACE plots ?  
(more water left ?)



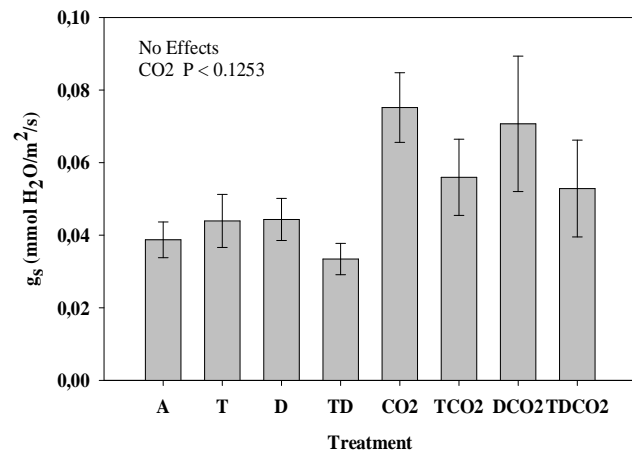
## Stomatal conductance at field conditions

Stomatal conductance at field conditions *Calluna vulgaris* august 2007



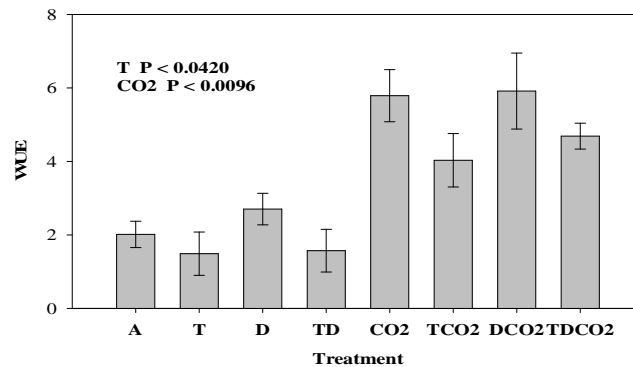
Parallel response in  
Stomatal conductance and  
transpiration

Stomatal Conductance at field conditions *Deschampsia flexuosa* august 2007

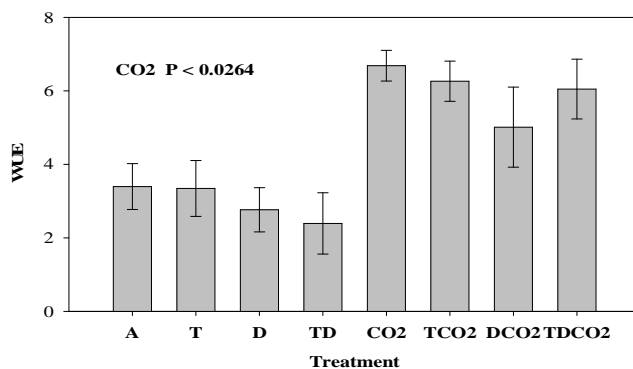


## Water use efficiency at field conditions

WUE at field conditions *Calluna vulgaris* august 2007



WUE at field conditions *Deschampsia flexuosa* august 2007



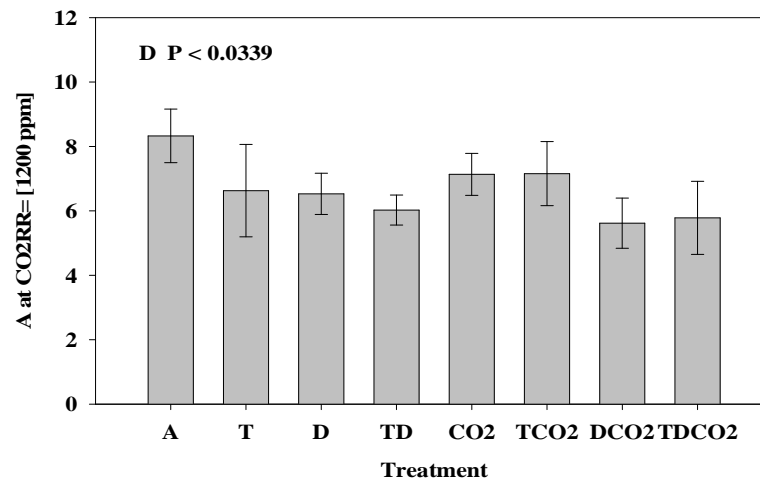
- [CO<sub>2</sub>] increases WUE – primarily via the increased CO<sub>2</sub> uptake
- *Deschampsia* had higher WUE in all treatments compared to *Calluna*
- [T] decreased WUE in *Calluna*
- No effect of [D]





## Max Photosynthesis (saturating light and CO<sub>2</sub>)

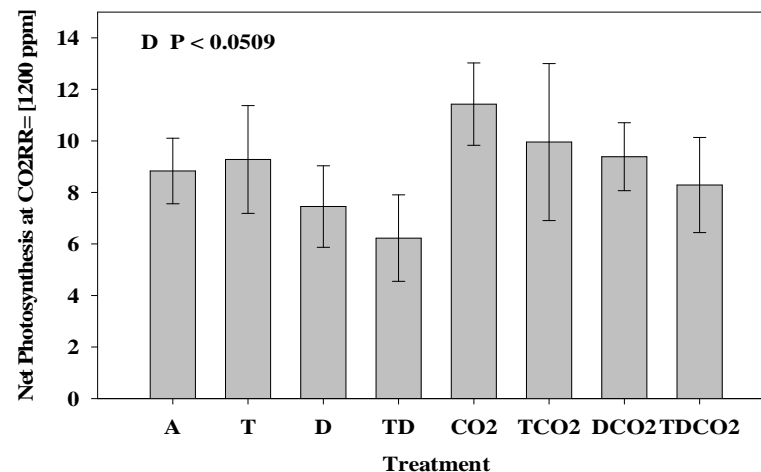
Max Net Photosynthesis *Calluna vulgaris* august 2007



Drought is reducing the photosynthetic capacity in both species.

No CO<sub>2</sub> effect : Acclimation to 510 ppm does not change the photosynthetic capacity significantly.

Max Net Photosynthesis *Deschampsia flexuosa* august 2007

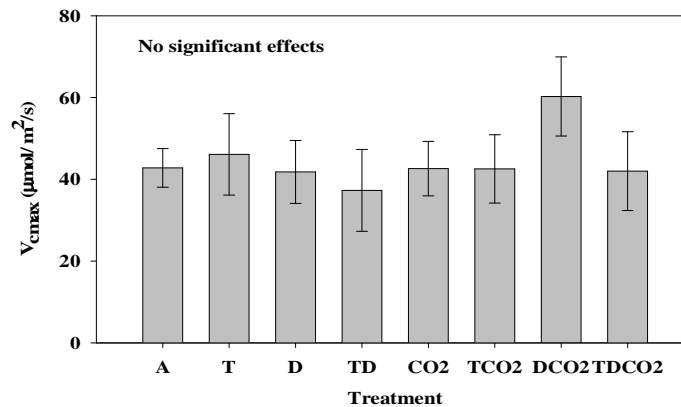


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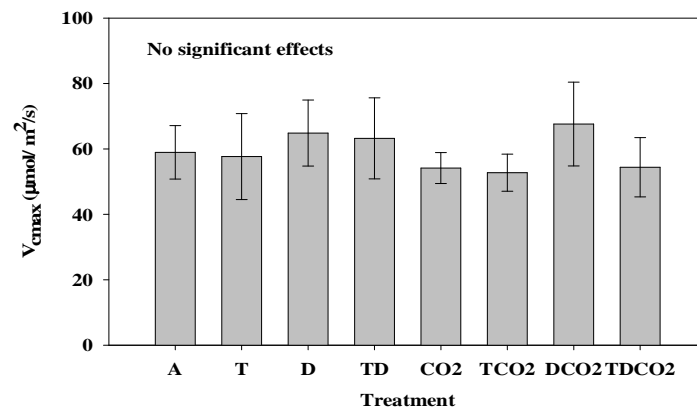
## Maximum velocity of Rubisco Carboxylation, $V_{\text{cmax}}$

Maximum rate of Rubisco carboxylation *Calluna vulgaris* august 2007



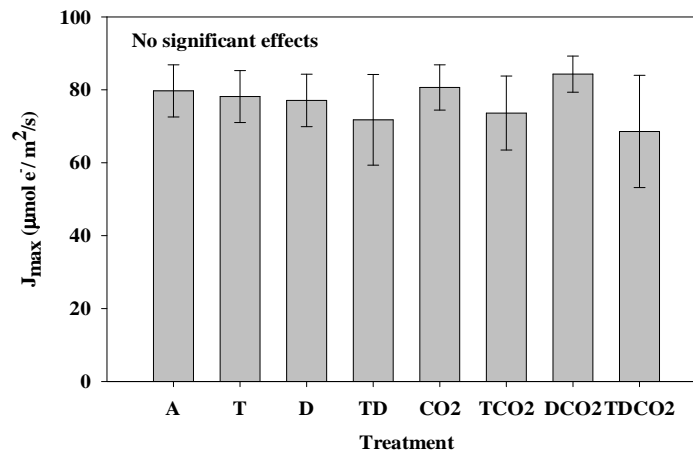
No effects

Maximum rate of Rubisco carboxylation *Deschampsia flexuosa* august 2007



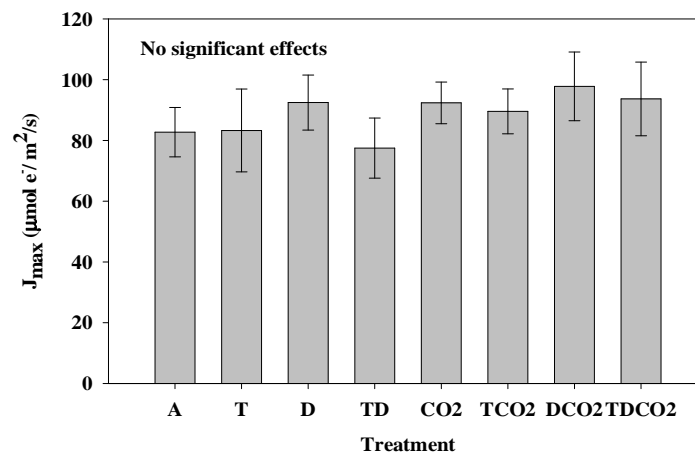
## Maximum electron transport, $J_{\max}$

Maximum rate of Electron transport for *Calluna vulgaris* august 2007



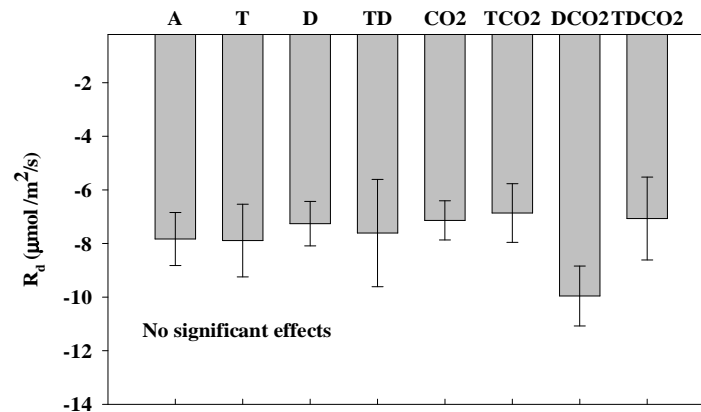
No effects

Maximum rate of Electron transport for *Deschampsia flexuosa* august 2007

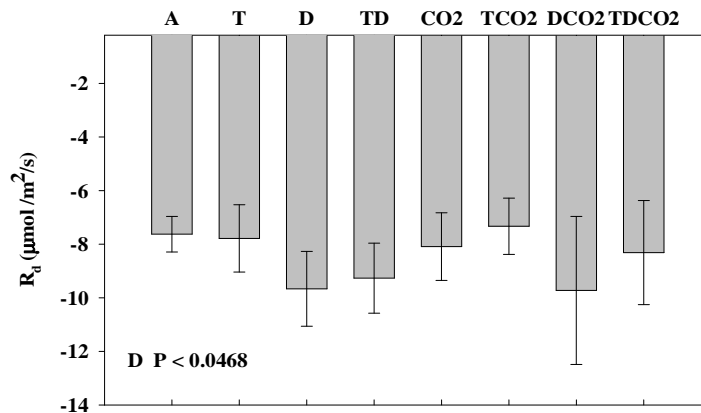


## Non-Photorespiratory CO<sub>2</sub> evolution

Non-Photorespiratory CO<sub>2</sub> evolution for *Calluna vulgaris* august 2007



Non-Photorespiratory CO<sub>2</sub> evolution for *Deschampsia flexuosa* august 2007



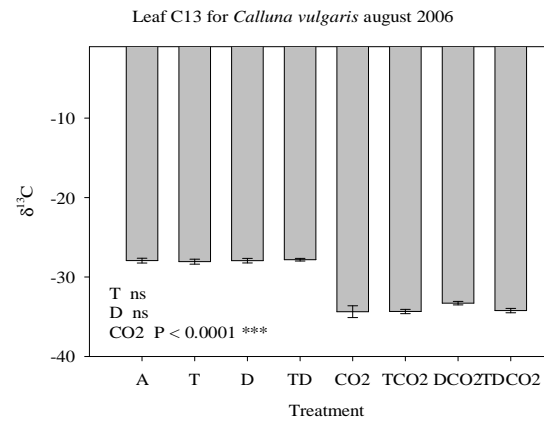
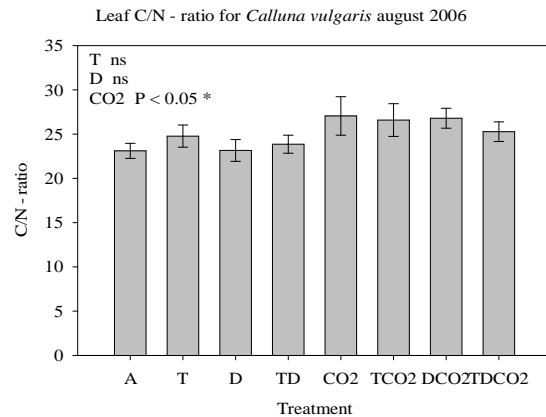
Drought increased  
respiration



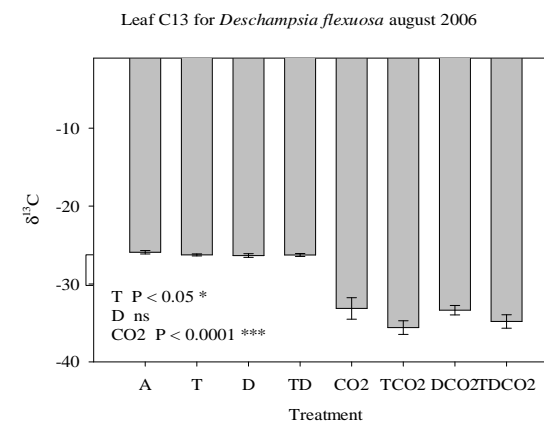
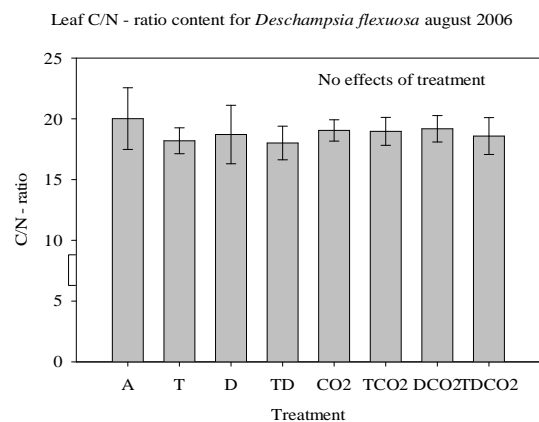
## Leaf C/N-ratio and $\delta^{13}\text{C}$

CO<sub>2</sub> effect:

Small C%  
decrease,  
Larger N%  
decrease



Added CO<sub>2</sub>  
other signal  
than atmo-  
spheric CO<sub>2</sub>



Small T-effect





## Responses and the plant strategies

Both species increases CO<sub>2</sub> uptake in [CO<sub>2</sub>] also in combinations with [D] and [T]

### *Characteristics*

- *Calluna*
  - Xeromorphic dwarf scrub
  - Deep roots, almost evergreen, strong water conducting tissues, long lived (1-3 year) xeromorphic leaves,
  - Benefits in the extended growth season when water availability is sufficient
  - Stand the drought
- *Deschampsia*
  - Perennial grass with several shoot generations
  - Low investment cost in leaves
  - Leaf wilting under stressfull conditions
  - Fast comeback after drought and benefits from the extended growth season
  - Probably more dependent of summer precipitation compared to *Calluna*



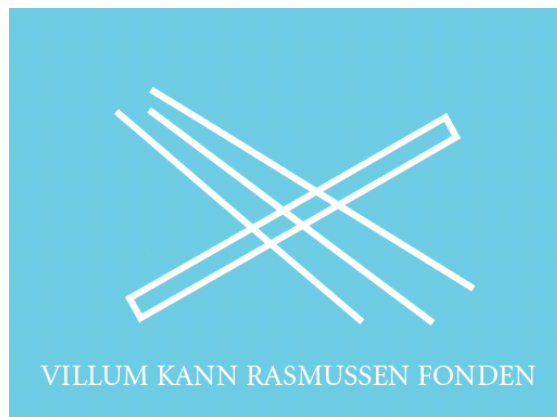
## Conclusions

- No down regulation of photosynthetic capacity (in this phase of the growing season)
- Under field conditions
  - Increased CO<sub>2</sub> uptake and WUE in response to elevated CO<sub>2</sub> for both species.
  - Stomatal regulation of particular importance:
    - Decreased *Calluna* CO<sub>2</sub> uptake when drought: Lower g<sub>s</sub>
    - No drought effect on *Deschampsia*: Unchanged g<sub>s</sub>
  - *Calluna* drought tolerant, whereas *Deschampsia* wilt a large proportion of the leaves and regrow them when water availability gets better
  - Elevated CO<sub>2</sub> increased *Calluna* leaf C/N ratio.
  - Both species benefits from extended growth season and shifts in phenological phases may impact the photosynthetic response
  - Cross scale evaluation of responses will strengthen the synthesis at ecosystem level.
- Long term multifactor experiments important for understanding the effects of Global Change on primary productivity and water relations.



Thanks to all in the CLIMAITE consortium, especially project manager Claus Beier

Elsam, Air Liquide, Danfoss and main sponsor: Villum Kann Rasmussen Foundation



Thanks for Your attention !

